Product User Manual for the "Air Mass Analysis" product (AMA, PGE12, v2.2)

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Support to Nowcasting and Very Short Range Forecasting

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2.0	16 September 2007	23	Initial version (content derived from various precursor documents on PGE12, most notably "Software User Manual for the SAFNWC/MSG: Scientific part for the PGE12")
2.1	23 February 2009	25	Update for the SAFNWC/MSG release 2009, mainly on new quality flag
2.1.1	8 September 2009	25	Minor – mainly editorial - updates for the SAFNWC/MSG release 2010. No scientific updates.
2.1.2	21 October 2010	26	Minor updates for the SAFNWC/MSG release 2011. No scientific updates.
2.2	15 February *2012*	24	Update for the SAFNWC/MSG release 2012

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1. INTRODUCTION

The Eumetsat "Satellite Application Facilities" (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (http://www.eumetsat.int). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, SAFNWC. The main objective of SAFNWC is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the SAFNWC webpage, http://www.nwcsaf.org. This document is applicable to the SAFNWC processing package for Meteosat satellites meteorological satellites, SAFNWC/MSG.

1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual for MSG Air Mass Analysis Products (PGE12).

This document contains practical information on the characteristics of the above mentioned products, on their applicability and limitations.

1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used to extract the MSG Air Mass Analysis Products (PGE12) are detailed in an Algorithm Theoretical Basis Document (AD. 4).

The latest validation of the algorithms used to extract the MSG Air Mass Analysis Products (PGE12) is reported in a validation report (AD. 5).

Instructions to install, configure and execute the SAFNWC/MSG software in order to extract the MSG Air Mass Analysis Products (PGE12) are detailed in a Software User Manual (AD. 3).

The Interface Control Documents (AD. 1) (for the External and Internal Interfaces of the SAFNWC/MSG) and (AD. 2) (MSG Output Product Format Definition) detail the input and output data format for the SAFNWC/MSG software.

1.3 SOFTWARE VERSION IDENTIFICATION

This document describes the products obtained from the PGE12 version included in the 2011 SAFNWC/MSG software package delivery.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

Rather than the previously used global regression, PGE12 v2.2 employs a locally adaptive scheme to deduce air mass classification from reference points. Provides air mass classification also over cloudy areas.

1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AMA	Air Mass Analysis
.cfm	PGE12 model configuration file (nominally at $SAFNWC/config/safnwc_pge12.cfm)
ECMWF	European Centre for Medium-range Weather Forecasts
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GEOS	Geostationary

HDF	Hierarchical data Format
HRIT	High Rate Information Transmission
IR	Infrared
LAM	Limited Area Model
LI	Lifted Index
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
PGE	Product Generation Element
QC	Quality Control
SAF	Satellite Application Facility
SAFNWC	SAF to support NoWCasting and Very-Short-Range Forecasting
SAI	Stability Analysis Imagery
SEVIRI	Spinning Enhanced Visible & Infrared Imager
SPhR	SEVIRI Physical Retrieval
SUM	Software User Manual
TPW	Total Precipitable Water
WV	Water Vapour

1.6 REFERENCES

1.6.1 Applicable Documents

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the document referred to applies.

Latest documentation can be found at the SAFNWC Help Desk at http://www.nwcsaf.org

Reference	Title	Code	Vers	Date
[AD. 1]	Interface Control Document for the External and Internal Interfaces of the SAFNWC/MSG	SAF/NWC/CDOP/INM/SW/ICD/1		
[AD. 2]	SAFNWC/MSG Output Products Format Definition	SAF/NWC/CDOP/INM/SW/ICD/3		
[AD. 3]	Software User Manual for the SAFNWC/MSG application	SAF/NWC/CDOP/INM/SW/SUM/2		
[AD. 4]	Algorithm Theoretical Basis Document for the "Air Mass Analysis" product (AMA, PGE12)	SAF/NWC/CDOP/ZAMG/SCI/ATBD/12		
[AD. 5]	Validation Report for “Air Mass Analysis” (AMA-PGE12, v2.1)	SAF/NWC/CDOP/ZAMG/SCI/VR/3	1.0	23/02/09
[AD. 6]	Validation Report for “Air Mass Analysis” (AMA-PGE12, v2.2)	SAF/NWC/CDOP/ZAMG/SCI/VR/5	1.0	23/11/11

Table 1: List of Applicable Documents

1.6.2 Reference Documents

The reference documents contain useful information related to the subject of the project. This reference document complements the applicable documents. For dated references, subsequent

amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the document referred to applies.

Latest documentation can be found at the SAFNWC Help Desk at http://www.nwcsaf.org

Reference	Title	Code	Vers	Date
[RD.1]	Scientific report on Validation and Tuning of MSG PGE12	SAF/NWC/IOP/ZAMG/SCI/VAL/1	1.0	19/08/05
[RD.2]				

Table 2: List of Referenced Documents

2. DESCRIPTION OF THE AIR MASS ANALYSIS (AMA) PRODUCTS

2.1 GOAL OF THE AIR MASS ANALYSIS (AMA) PRODUCTS

PGE12 of the SAFNWC/MSG provides several products considered useful for air mass analysis. Well-established concepts from literature were taken and implemented/adapted for a use with SEVIRI imagery, supplemented - where necessary - by NWP products:

- A rather classical classification of air masses as function of total precipitable water and temperature derived from satellite data.
- Tongues of equivalent-potential temperature indicate protruding warm and moist air in which severe local convection is most likely to occur (Carlson, 1991; Bader et al., 1995; ZAMG, 2005). Therefore, an objective determination of the ridge lines of the equivalent-potential temperature field is performed.
- Indication of areas where there is high probability for the initiation of convection: the areas at the leading edge of frontal cloud bands. Therefore, the pre-frontal regions with high gradients of equivalent-potential temperature are marked.
- Motivating a sub-product of objectively determined dark stripes in WV imagery, dry air in the upper troposphere is another air mass type that is important in two respects:
  - Dry air overrunning frontal zones is connected to the development of intensive convection at the leading parts of fronts (ZAMG, 2005).
  - The boundaries between wet and dry air (boundaries between gray and black stripes in WV) are preferred zones for initiation of convection (Martín et al., 1999; ZAMG, 2005).

2.2 OUTLINE OF AIR MASS ANALYSIS (AMA) ALGORITHMS

2.2.1 Air mass classification algorithm outline

The implemented scheme is based on finding cloudfree reference pixels where IR13.4 "almost certainly" indicates the correct air mass type. The motivation to use IR13.4 is that this is the only IR channel with a weighting function not peaking at the earth's surface, thus mitigating land heating effects. For each cloudfree pixel (that has not been flagged as reference pixel) or pixel with a cloud top height not exceeding 2000 m, the closest reference pixels are sought in the surrounding. If they all signal the same air mass, the decision is easy. If there are different air masses, categories "arctic" to "equatorial" are numerically translated to values of a "fractional air mass code" (hereafter FAMC) from 1.0 to 4.0, and the FAMC at the considered pixel is obtained via weighted interpolation in the variables

- WV7.3 brightness temperature,
- longitude, and
- latitude.

The permissibility of clouds up to a height threshold of 2000 m derives from the use of the WV7.3 channel whose signal is not contaminated by low clouds. Finally, a series of purely geometrical methods is applied to fill the not yet classified areas (including those with high clouds) with the most probable airmass classification: a neighbourhood inspection searching for a majority decision from surrounding already-classified pixels, followed by gap filling which determines the size of gaps in horizontal and vertical direction, respectively, and assigns the pixels along those lines in a 50-50 split to the adjacent classifications.

After some releases based on the NWCSAF product "total precipitable water" (TPW), v2008 switched over to a NWP-derived TPW. TPW thresholds between continental and maritime air masses are dependent on the numerical values of the functions obtained in the regressions: For "perfectly" arctic, polar, tropical and equatorial air, the thresholds are respectively 0.48, 1.13, 2.66 and 6.25 cm.

In case that the user ordered inclusion of stability information, a "stable"/"unstable" attribute is assigned to each cloudfree pixel on the basis of simple SPhR LI thresholding.

2.2.2 WV dark stripe detection algorithm outline

The detection of dark stripes has the following principal steps:

(1) For each pixel, it is checked whether the pixel is dark enough to be eligible, i.e. whether it is darker than an empirical threshold (brightness temperature has to be ≥-40.5°C).

(2) For each candidate pixel it is verified that it is darker than (most of) its neighbours.

(3) The pixels passing the test undergo postprocessing: a contouring algorithm is applied to encircle sufficiently extended conglomerates of such pixels.

2.2.3 'Ridge line' product algorithm outline

The SAFNWC/AMA package determines the ridge line of the equivalent-potential temperature derived from NWP forecast fields of temperature and humidity as follows:

- Computation of a "pseudo curvature vorticity" which describes the curvature of the NWP 850 hPa equivalent-potential temperature isolines.
- For each point, determination of number of neighbours (N_+) with higher values of "pseudo curvature vorticity" ("less anticyclonic" neighbours). Generally, a point should have $N_+ \geq 6$ in order to be eligible. However, it can be shown (and justified) that occasionally also points with $N_+=4$ or $N_+=5$ need to be taken into account. A negative "pseudo curvature vorticity" is a natural further prerequisite for eligibility. Then, a ridge of the function is tracked by:
- repeated determination of the direction of smallest descent of the N_+ function, starting from a local minimum.

2.2.4 Gradient zone product algorithm outline

Main criterion for indicated gradient zone: sufficiently extended zone of gradient above an empirical threshold; either the gradient's x-component or y-component has to have the same sign all over the indicated zone (otherwise two gradient zones would be joined which for geometrical reasons are unlikely to represent the same prefrontal region). The product is "cleaned" in such a manner that gradient zone markers are withdrawn in regions where the SAFNWC/MSG cloud mask reports clouds (in those areas, the product shows pixel values of an IR channel). Note that the "large-scale" check on the gradient zone comes first, i.e. due to cloud masking, some small patches of indicated gradient may appear in the final product.

2.3 DESCRIPTION OF AIR MASS ANALYSIS (AMA) OUTPUTS

This product consists of several sub-products with different output format:

(1) The air mass classification product (AMA_CL) provides air mass designations at pixel resolution. The product format is HDF5**.** From v2008 on, the "gradient zone of the NWP equivalent-potential temperature field" product is an image-like product packed into the same

HDF5 file (product code AMA_GZ). There is moreover a quantity AMA_QUALITY, which represents a quality flag implemented in a first version in v2009 and augmented in subsequent releases.

The number of air mass classes in the current version (PGE12 of SAFNWC/MSG release v2012) is 9 or 17 (depending on whether the user turns the LI inclusion option off or on) +8 placeholders for possible future use, with the following coding (if SPhR LI inclusion is not selected or the SPhR LI product is missing, the lower numbers are selected and classes 13 to 24 do not appear):

Code	Name
0	Unclassified
1	Arctic, continental, stable
2	(Arctic, reserved for future use)
3	Arctic, maritime, stable
4	Polar, continental, stable
5	(Polar, reserved for future use)
6	Polar, maritime, stable
7	Tropical, continental, stable
8	(Tropical, reserved for future use)
9	Tropical, maritime, stable
10	Equatorial, continental, stable
11	(Equatorial, reserved for future use)
12	Equatorial, maritime, stable
13	Arctic, continental, unstable
14	(Arctic, reserved for future use)
15	Arctic, maritime, unstable
16	Polar, continental, unstable
17	(Polar, reserved for future use)
18	Polar, maritime, unstable
19	Tropical, continental, unstable
20	(Tropical, reserved for future use)
21	Tropical, maritime, unstable
22	Equatorial, continental, unstable
23	(Equatorial, reserved for future use)
24	Equatorial, maritime, unstable

The parameter AMA_QUALITY can assume values in the range 0-28 or 255, with the following meanings:

Code	Meaning
0	no continuity-type QC possible because pixel not classified in at least one of the considered AMA_CL fields
1	no change in thermal category (i.e. arctic, polar, tropical or equatorial) and moisture category (maritime vs. continental) between current and previous slot
2	change in moisture category
3	change in thermal category
4	change in both moisture and thermal category
255	Air mass classification suspended (either intended by the user or due to some problems; seek additional log messages for further explanation)

A value of 8 is added if the pixel is one with high clouds (i.e. cloud top height above 2000 m) and the air mass classification hence was obtained purely by geometric algorithms.

Even if the user opted for SPhR LI inclusion, the classification cannot include stability information in all cloudy areas (low and high) as SPhR does not provide values there; the AMA_QUALITY parameter is increased by 16 in order to signal this in the output file (if the stability product is missing as a whole for whatever reason, 16 is added for all analysed pixels).

The gradient zone product has 128 different count values with the following meaning:

Code	Name
0	cloudfree, no gradient zone identified
1	cloudfree, gradient zone identified
2-127	cloudy; information on gradient zone not relevant (since only of significance in prefrontal areas); IR greyscale image shown instead (taken from the 13.4 micron channel)

Additionally, the whole field might be filled with value 255, signalling that the entire gradient zone has been suspended (either intended by the user or due to some problems; seek additional log messages for further explanation).

The names of the output files adhere to the SAFNWC/MSG convention on HDF5 file naming.

(2) Additionally, the coordinates of special lines are provided. In order to provide the user with the utmost flexibility, these lines are not super-imposed on the image but are described in separate BUFR files; the used BUFR edition is No. 4. The employed naming convention mimics the SAFNWC system for BUFR format files to the extent possible (it actually adds only the designation of the sub-product: a) dark stripes in WV imagery: "WVstripe" b) ridge lines of the equivalent-potential temperature field:"T-Ridge".

Field Name	Description	Data Type	Value
Product_id (1)	Identifier for SAFNWC	6 char.	"SAFNWC"
Field Separator	Separator	1 char.	" " (underscore)
Product_id (2)	Spacecraft identifier	4 char.	"MSG*i*" (where *i* is an integer)
Field Separator	Separator	1 char.	" " (underscore)
Product_id (3)	product name	4 char.	The PGE-specific code "AMA_".
Field Separator	Separator	1 char.	" " (underscore)
Product_id (4)	Date/time of acquisition of SEVIRI image	12 char.	"yyyymmddhhmm"
Field Separator	Separator	1 char.	" " (underscore)
Product_id(5)	Name of processed region	12 char.	Taken from the entry under REGION in the region configuration file and padded by underscores where needed.
Field Separator	Separator for extension	1 char.	"."
Product_id(6)	Name of sub-product	variable number of char.	Name of the sub-product coded in the BUFR file. One of the following: "WVstripe", "T-Ridge"
Field Separator	Separator for extension	1 char.	"."
Extension	Extension of the product name to indicate the type of data	3 char.	buf

Table 3: File name components of AMA BUFR output

The template of the BUFR files is as follows:

101000 SPECIFICATION OF THE REPLICATION
031002 EXTENDED DELAYED DESCRIPTOR REPLICATION FACTOR
301023 expands to:
005002 LATITUDE (COARSE ACCURACY)

006002 LONGITUDE (COARSE ACCURACY)
011021 RELATIVE VORTICITY[1]

The output files contain as many BUFR records as there are identified black stripes or ridge lines, respectively.

[1] This entry appears only in the ridge line product. The product derivation starts with the computation of a "pseudo curvature vorticity" which describes the curvature of the NWP 850 hPa equivalent-potential temperature isolines. The internal absolute value of this quantity at the starting point of the ridge line tracking (=a local maximum of anticyclonicity) is provided. It should be a measure how distinctive the pattern is (and therefore can be exploited to filter weakly developed ridges (via a user-set keyword in the PGE12 model configuration file)).

3. IMPLEMENTATION OF AIR MASS ANALYSIS (AMA)

AMA is extracted by PGE12 of the SAFNWC/MSG software package. Detailed information on how to run this software package are available in the "Software User Manual for the SAFNWC/MSG application" [AD. 3].

The implementation of the PGE12 software follows the general implementation of components of the SAFNWC/MSG software (see the software part of the Software Users Manual of the SAFNWC/MSG software for more details).

Basically, the following steps are needed to run the PGE12 software:

1. Create or update configuration files (system, region, model and run configuration files) according to their format (see the Interface Control Document ICD/1 for the External and Internal Interfaces of the SAFNWC/MSG). Files are situated in $SAFNWC/config. In particular, if the optional SPhR LI inclusion of PGE12 is desired, set the entry INCORPORATE_LI in the model configuration file $SAFNWC/config/safnwc_pge12.cfm to YES (default in the delivery is: NO). If only a sub-selection of PGE12 products is required, modify the relevant entries CLASSIFICATION_PRODUCT, WV_STRIPE_PRODUCT, RIDGE_LINE_PRODUCT, GRADIENT_ZONE_PRODUCT in the model configuration files accordingly (default in the delivery is: “YES”, i.e. all products are ordered; change to “NO” if a certain sub-product shall be suspended).
2. Algorithm configuration files are situated in the directory “$SAFNWC/import/Aux_data/PGE12”. These PGE12 input files are provided with the software package, installed together with it, and are not foreseen for modification by users.
3. The cloud mask (CMa) input (which is the output of PGE01 of the SAFNWC/MSG) matching slot and region has to be made available in the directory “$SAFNWC/export/PGE01”
4. The cloud top temperature and height (CTTH) input (which is the output of PGE03 of the SAFNWC/MSG) matching slot and region has to be made available in the directory “$SAFNWC/export/PGE03”
5. Provided the user requested the inclusion of optional stability analysis imagery (SPhR LI) input, which is an output of PGE13 of the SAFNWC/MSG, SPhR data matching slot and region have to be made available in the directory “$SAFNWC/export/PGE13”
6. For producing the products based on NWP data, the reprocessed NWP data have to be available in the DATABUF directory “$SAFNWC/tmp”.
7. Ensure that the SEVIRI image file in HRIT format (mandatory input) is available in the directory $SAFNWC/import/SEVIRI_data/.
8. Make sure that the environment variable $SAFNWC is set. The environment variable $BUFR_TABLES need also be set (as $SAFNWC/src/bufr_000360/bufrtables/)
9. Make sure that the following supplementary files are available:
   a) $SAFNWC/src/bufr_000360/bufrtables/B0000000000098002001.TXT,
   b) $SAFNWC/src/bufr_000360/bufrtables/D0000000000098002001.TXT,
   c) $SAFNWC/import/Aux_data/Topo_+000.00.dat (for METEOSAT-8: Topo_+009.50.dat)

   These files are not included in the PGE12 distribution because they are packed into other libraries also delivered with SAFNWC/MSG. The listed files should be available after

unpacking the full SAFNWC/MSG SW package, as described in the relevant documentation.

Then, the processing of PGE12 is automatically monitored by the task manager (see the Software Users Manual for the Task Manager of the SAFNWC/MSG software).

Submitting PGE12 in stand-alone mode, not using the task manager:

Ensure that all required input data are available in their respective directories, and that pre-requirements listed under items 1-9 are fulfilled.

PGE12 can be called as follows (from the directory where it is situated):

./PGE12 YYYYMMDDhhmm region_configuration_file model_configuration_file

Example:
./PGE12 201103281145 myregion.cfg safnwc_pge12.cfm

4. INPUTS AND CONFIGURABLE PARAMETERS FOR AIR MASS ANALYSIS (AMA)

4.1 LIST OF INPUTS

4.1.1 Air mass classification product

- SEVIRI IR imagery, channels 7.3 and 13.4
- NWP information (temperature und humidity information in various levels) in DATABUF format (as preprocessed by the SAFNWC/MSG application)
- SAFNWC/MSG product "Cloud mask", which is the output of PGE01 of the SAFNWC/MSG
- SAFNWC/MSG product "Cloud top temperature and height", which is the output of PGE03 of the SAFNWC/MSG
- Optionally: Lifted Index imagery (SPhR LI), which is output of PGE13 of the SAFNWC/MSG

4.1.2 WV dark stripe product

- SEVIRI WV image, channel 6.2

4.1.3 'Ridge line' product

- ECMWF NWP GRIB data (temperature und humidity information in 850hPa).

4.1.4 'Gradient zone of equivalent-potential temperature' product

- ECMWF NWP data (temperature und humidity information in 850hPa) in DATABUF format (as preprocessed by the SAFNWC/MSG application)
- SEVIRI IR imagery, channel 13.4
- SAFNWC/MSG product "Cloud mask", which is the output of PGE01 of the SAFNWC/MSG

4.2 CONFIGURABLE PARAMETERS FOR AIR MASS ANALYSIS (AMA)

The configurable parameters can be found in the model configuration file for the PGE12, which is separated into two parts. The first section contains three parameters that can be set by the user (Then, starting with the entry PGE_ID, the rest of the model configuration file is constituted by a section that should be touched only by the institute responsible for development/maintenance of PGE12, which at present is ZAMG.)

Keyword	Description	Type	Possible Value(s)
CLASSIFICATION_PRODUCT	Decide whether the air mass classification product is computed	chain of characters	YES or NO
WV_STRIPE_PRODUCT	Decide whether the WV dark stripe product is computed	chain of characters	YES or NO

Keyword	Description	Type	Possible Value(s)
RIDGE_LINE_PRODUCT	Decode whether the 'ridge line' product is computed	chain of characters	YES or NO
GRADIENT_ZONE_PRODUCT	Decide whether the 'gradient zone' product is computed	chain of characters	YES or NO
INCORPORATE_LI	Decide whether the NWCSAF SPhR LI product should be incorporated in the AMA air mass classification process.	chain of characters	YES or NO
RL.MinLength	The minimum length in terms of NWP grid points a ridge line has to have in order to appear in the output	integer	all (yet values <2 are set to 2 internally)
RL.MinAbsCurvature	The minimum anticyclonic curvature an extremum has to have in order to be eligible as a starting point of a ridge-line tracking	float	all (yet values < 0. are set to 0. internally)

The first five entries are straightforward to set (see also section 2.3). The other two parameters define the filtering of the ridge line product. From v2008 on, this product takes the NWP GRIB file provided by the user in $SAFNWC/import/NWP_data as it is, and analyzes ridge lines on the NWP grid. Thereby, LAM output became permissible as input; on the other hand, this means that the developers can no longer control the meaning of "significant ridge lines" in terms of length of the ridge line and curvature of the isolines. Length and curvature are encoded in the BUFR telegrams (see section 2.3) and the two entries in the model configuration enable the user after some experience with his/her own NWP data to set the filtering parameters appropriately, if wished so. At delivery, the configuration parameters are basically functionless (just reflecting that a line should consist of two points and a ridge is not cyclonic!).

5. AIR MASS ANALYSIS (AMA) VALIDATION

5.1 SUMMARY OF AIR MASS ANALYSIS (AMA) VALIDATION RESULTS

The air mass analysis products face some conceptual difficulties w.r.t. to their validation (described in more detail in the two AMA validation reports [RD.1] and [AD.5]). In this situation, the issues of validation in [AD.5] were subjective judgements on

- whether the indicated ridge lines, stripes… were analysed in a similar fashion as a trained meteorologist would do
- whether these analyses are stable in time.
- whether the analyses are stable against changes in the region selected by a user.

In [RD.1], moreover actually observed cases of convection were used as starting points and it was investigated whether these were somehow predictable from the AMA products.

Recently, the air mass classification was judged against tropopauses derived from IASI and ATOVS level-2 profiles [AD.5, Test 5]. A slight change of algorithmic thresholds was proposed as a result, and these changes were implemented in v2009.

The latest validation report [AD. 7] informs about adaptations that allow to derive air mass classifications in cloudy areas and on a global scale including the Southern Hemisphere.

In summary, based on those (mostly) subjective evaluations, the products of v2012 give no reason for serious concern. The two sub-products being judged as hardly acceptable in [RD.1] (namely: “air mass classification” and “gradient zone”) saw a complete refurbishment of their concepts, so the criticism expressed in this document today no longer holds.

5.2 TYPICAL KNOWN PROBLEMS AND RECOMMENDATION FOR USE

Pattern recognition routines generally benefit from large analysis area (the more one sees from the surrounding, the more certain is the analysis of the local pattern). It is therefore in principle possible (even though the robustness for the common 512x512-pixel region has been verified) that users select a too small analysis region. Note that the flexibility on the region was introduced in v2008 in response to an (understandable) user request, not on scientific grounds (before that, PGE12 used a large region covering all of Europe and substantial parts of the Atlantic Ocean).

With the tuning process being mainly done on subjective reasoning, a certain risk of differing perception among different individuals cannot be ruled out.

Most sub-products of PGE12 are based on the objective recognition of certain patterns that MAY indicate imminent convective activity. None of these features is by itself a trigger of convective activity. In fact, there is no doubt that in the majority of cases or over most of the extension of such a phenomenon, no severe weather is found. Consequently, they have always to be considered in conjunction with other relevant meteorological material, not on their own.

Unfortunately, with respect to setting the configurable parameters for ridge line detection (section 4.2), no guidelines can be presented at the time being, as it is hardly possible to cover all the different NWP input users may provide.

6. EXAMPLES OF AIR MASS ANALYSIS (AMA) VISUALISATION

Figure 1 shows the visualization of the BUFR products: WV stripes and ridge lines of equivalent potential temperature. *Figure 2* gives an example how the air mass classification product may be presented to the user, and *Figure 3* provides a glance on a gradient zone output.

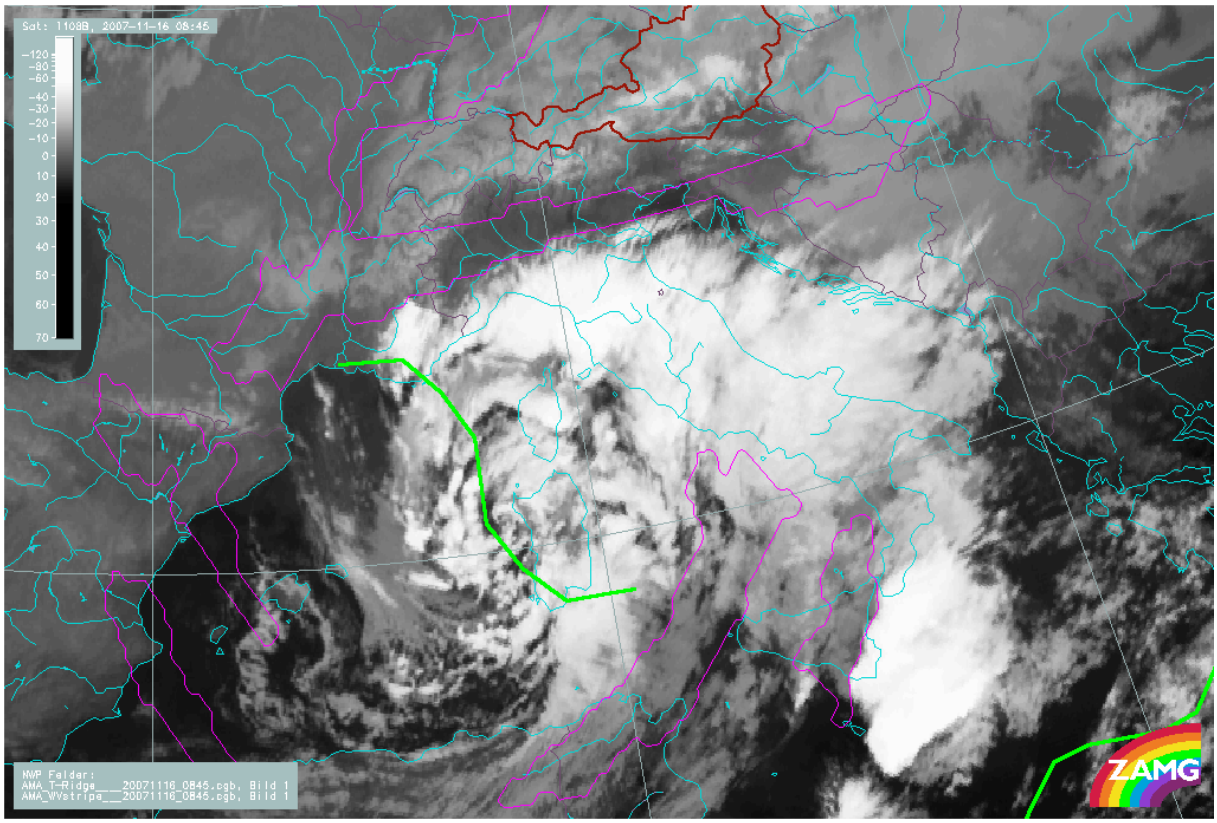

Figure 1: Ridge line detection for an equivalent-potential temperature field (ECMWF forecast data); the green lines indicate the positions of the automatically detected ridge axes. Magenta isolines encircle the WV dark stripes that are identified by the respective part of the SAFNWC AMA package. Case: 16 November 2007, 0845 UTC.

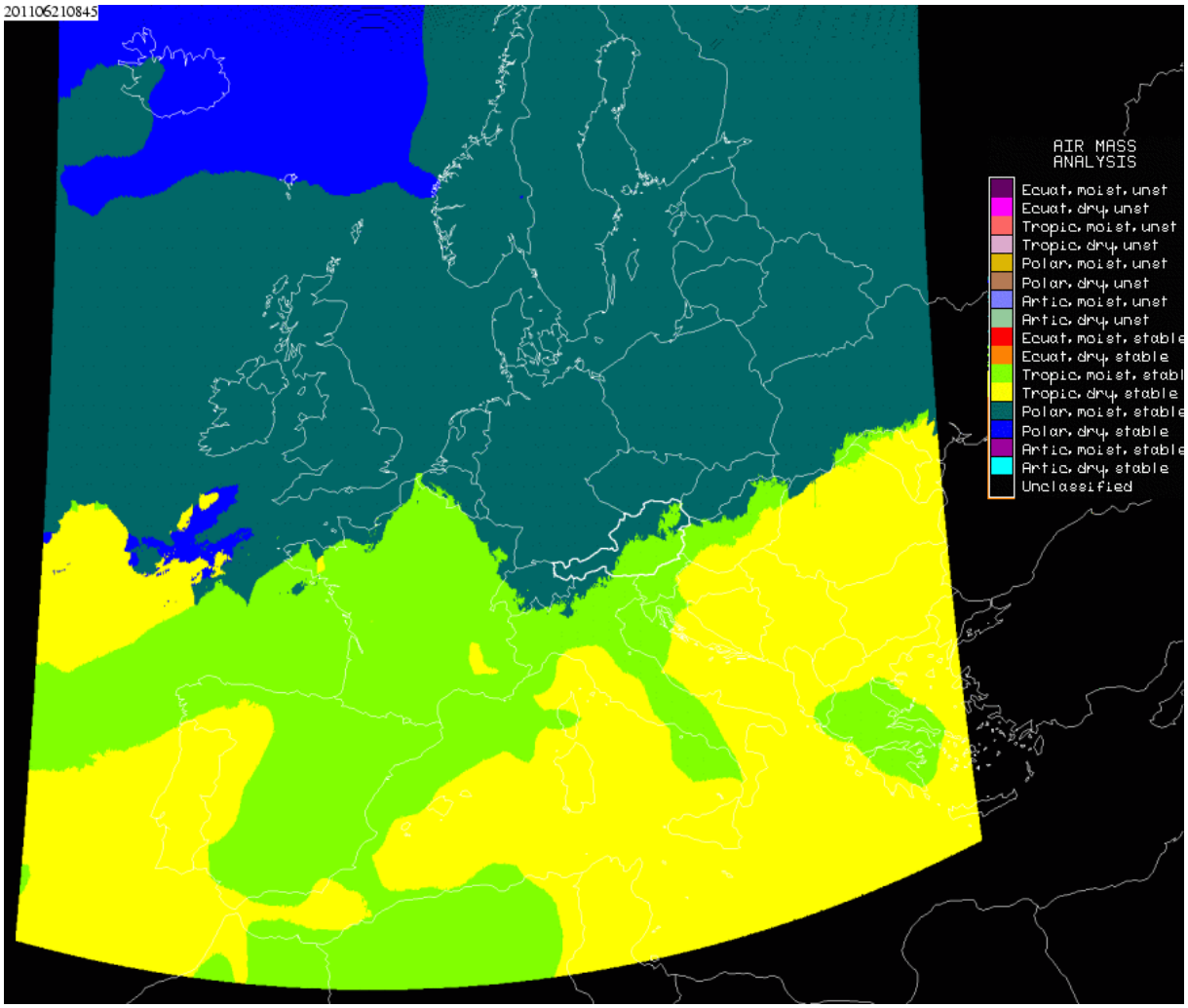

Figure 2: Example display of the SAFNWC air mass classification product. Case of 17 February 2012, 1130 UTC. Prevailing on the display is tropical+continental and polar+maritime air (see attached colour legend; optional stability inclusion was turned off).

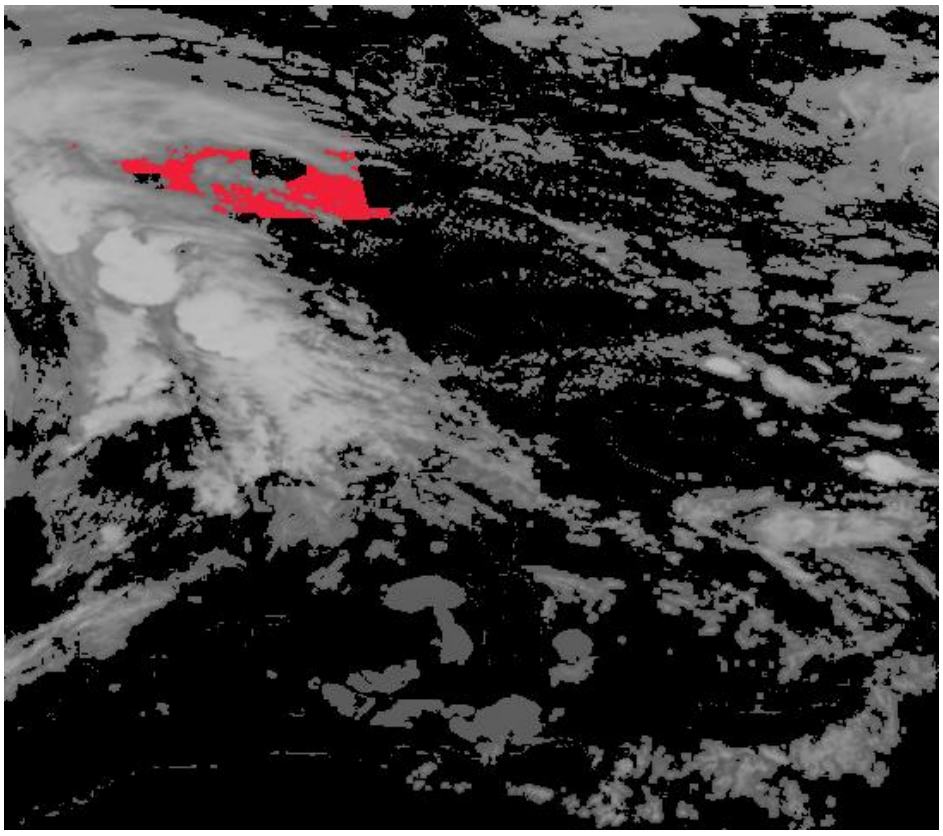

Figure 3: Example display of the SAFNWC gradient zone product, as seen in the HDFView software. Case of 19 June 2007, 1630 UTC, gradient zone painted red, cloudy pixels plotted in greyscale.

For convenience, the source code of a FORTRAN-90 program that draws similar graphics as the one in *Figure 1* is included below. Users are probably most interested in the sections on BUFR decoding, hence these parts are highlighted by boldface printing. The BUFRDC software, freely available from ECMWF, is used here (subroutines PBOPEN, PBBUFR, BUFREX, PBCLOSE); note that the BUFR decoding sections are virtually identical for the two sub-products. The other parts of the program mainly contain commands to accomplish the graphics output by the MAGICS++ package (which in principle is able to digest BUFR input directly; this functionality is, however, not exploited here in order to also support users of other visualization software)..

```
!       THIS IS A DEMO BUFR DECODING ROUTINE FOR LONGITUDE/LATITUDE INFORMATION
!       SUBMITTED BY SAFNWC AMA ROUTINES
!       AUTHOR:         ALEXANDER JANN / ZAMG / VIENNA, AUSTRIA
!       CREATION DATE: 12/05/2011
!       THIS IS INTENDED TO REPRESENT A USEFUL SUPPORT TO USERS OF THE
!       SAFNWC/MSG SOFTWARE PACKAGE, BUT COMES WITHOUT WARRANTY OF ANY KIND.

        PROGRAM SAFNWC_AMA_BUFR
        PARAMETER(    JSUP=9, JSEC0=3, JSEC1=40, JSEC2=4096, JSEC3=4,  &
                      JSEC4=2, JELEM=160000, JBUFL=300000, JBYTE=440000, KELEM=160000, &
                      JBPW=32, KVALS=4096000)

        DIMENSION KSUP(JSUP)  , KSEC0(JSEC0), KSEC1(JSEC1)
        DIMENSION KSEC2(JSEC2), KSEC3(JSEC3), KSEC4(JSEC4)
        INTEGER, DIMENSION(JBUFL) :: KBUFF
        REAL*8,  DIMENSION(KVALS) :: VALUES
```

```
      REAL, DIMENSION(200000) :: CONTOURX, CONTOURY, CONTOURZ
      CHARACTER (LEN=64), DIMENSION(KELEM) :: CNAMES
      CHARACTER (LEN=24), DIMENSION(KELEM) :: CUNITS
      CHARACTER (LEN=80), DIMENSION(KELEM) :: CVALS


!     OPEN MAGICS, DEFINE GRAPHICAL DEVICE AND FIX GEOGRAPHICAL AREA

      CALL POPEN
      CALL PSETC ('OUTPUT_FORMAT','PS')
      CALL PSETC ('OUTPUT_NAME','PGE12a')
      CALL PSETC ('PAGE_ID_LINE','OFF')
      CALL PSETC ('SUBPAGE_MAP_PROJECTION','POLAR_STEREOGRAPHIC')
      CALL PSETC ('SUBPAGE_MAP_AREA_DEFINITION','CORNERS')
      CALL PSETR ('SUBPAGE_MAP_VERTICAL_LONGITUDE',0.0 )
      CALL PSETR ('SUBPAGE_LOWER_LEFT_LONGITUDE',-29.5)
      CALL PSETR ('SUBPAGE_LOWER_LEFT_LATITUDE', 22.6)
      CALL PSETR ('SUBPAGE_UPPER_RIGHT_LONGITUDE',73.1)
      CALL PSETR ('SUBPAGE_UPPER_RIGHT_LATITUDE', 56.3)
      CALL PCOAST

!     DECODE AND VISUALIZE THE THETA-E RIDGE LINE PRODUCT

      IRET=0
      CALL PBOPEN (IUNIT,'SAFNWC_MSG2_AMA__201105120800_EUROPE_____.T-Ridge.buf', &
       'r',IRET)
      IF (IRET .NE. 0) GOTO 201
      CONTOURX(:)=-999.
      NPOI_TOTAL=1
RLOOP: DO I=1,200000
            CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
            IF (IRET .EQ. -1) EXIT RLOOP ! done with file
            KBUFL=KBUFL/4+1
            KEL=KELEM
            CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4, &
             KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)
            IF (KERR .NE. 0) THEN
                  WRITE(6,*) 'ERROR DURING DECODING'
                  GOTO 201
            END IF

            NPOI=INT(VALUES(1))
            CONTOURY(NPOI_TOTAL:NPOI_TOTAL+NPOI-1)=VALUES(2:2*NPOI:2)
            CONTOURX(NPOI_TOTAL:NPOI_TOTAL+NPOI-1)=VALUES(3:2*NPOI+1:2)
            NPOI_TOTAL=NPOI_TOTAL+NPOI+1
      END DO RLOOP

!     PLOT THE RIDGE LINES

      CALL PSETC ('POLYLINE_LINE_COLOUR','GREEN')
      CALL PSETI ('POLYLINE_LINE_THICKNESS',3)
      CALL PSET1R ('POLYLINE_INPUT_LONGITUDES',CONTOURX(1:NPOI_TOTAL-1),NPOI_TOTAL)
      CALL PSET1R ('POLYLINE_INPUT_LATITUDES',CONTOURY(1:NPOI_TOTAL-1),NPOI_TOTAL)
      CALL PSET1R ('POLYLINE_INPUT_VALUES',CONTOURZ(1:NPOI_TOTAL-1), NPOI_TOTAL)
      CALL PLINE
201   CALL PBCLOSE(IUNIT,IRET)

!     DECODE AND VISUALIZE THE WV STRIPE PRODUCT
```

```
      IRET=0
      CALL PBOPEN (IUNIT,'SAFNWC_MSG2_AMA__201105120800_EUROPE_____.WVstripe.buf', &
       'r',IRET)
      IF (IRET .NE. 0) GOTO 203
      CONTOURX(:)=-999.
      NPOI_TOTAL=1
SLOOP:  DO I=1,200000
            CALL PBBUFR (IUNIT,KBUFF,JBYTE,KBUFL,IRET)
            IF (IRET .EQ. -1) EXIT SLOOP ! done with file
            KBUFL=KBUFL/4+1
            KEL=KELEM
            CALL BUFREX (KBUFL,KBUFF,KSUP,KSEC0,KSEC1,KSEC2,KSEC3,KSEC4, &
             KEL,CNAMES,CUNITS,KVALS,VALUES,CVALS,KERR)

            IF (KERR .NE. 0) THEN
                  WRITE(6,*) 'ERROR DURING DECODING'
                  GOTO 203
            END IF

            NPOI=INT(VALUES(1))
            CONTOURY(NPOI_TOTAL:NPOI_TOTAL+NPOI-1)=VALUES(2:2*NPOI:2)
            CONTOURX(NPOI_TOTAL:NPOI_TOTAL+NPOI-1)=VALUES(3:2*NPOI+1:2)
            NPOI_TOTAL=NPOI_TOTAL+NPOI+1
      END DO SLOOP

!     PLOT THE BLACK STRIPE CONTOURS

      CALL PSETC ('POLYLINE_LINE_COLOUR','MAGENTA')
      CALL PSET1R ('POLYLINE_INPUT_LONGITUDES',CONTOURX(1:NPOI_TOTAL-1),NPOI_TOTAL)
      CALL PSET1R ('POLYLINE_INPUT_LATITUDES',CONTOURY(1:NPOI_TOTAL-1),NPOI_TOTAL)
      CALL PSET1R ('POLYLINE_INPUT_VALUES',CONTOURZ, NPOI_TOTAL)
      CALL PLINE

203   CONTINUE
      CALL PBCLOSE(IUNIT,IRET)
      CALL PCLOSE

      END
```

7. REFERENCES

Bader, M.J., Forbes, G.S., Grant, J.R., Lilley, R.B.E., and Waters, A.J. (Eds.) (1995): Images in weather forecasting. Cambridge University Press, Cambridge.

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ZAMG (2005): Manual of synoptic satellite meteorology: Conceptual models. CD-ROM, version 6.0 (available from ZAMG and online on http://www.zamg.ac.at/docu/Manual/start.htm).